PHOTOELECTRIC EFFECT

Students:______________________

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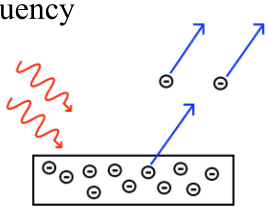
Objective

To determine the value of Planck's constant, work function, and cutoff frequency

Introduction

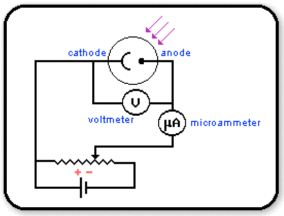


Electromagnetic radiation (such as visible light) is absorbed by metals and electrons are release (Fig. 1) in exchange if frequency of radiation is above a certain metal-dependent threshold (cutoff frequency). The cutoff frequency f_0 (and the corresponding wavelength) is the minimum frequency required of an incident photon in order to overcome the work function of the metal and free an electron:

$$hf_0 = hc/\lambda = W. \tag{1}$$

If the energy $E = hf$ of the incident photon is larger than the work function $W = hf_0$, then the energy surplus of the incident photon is taken by the photoelectron as kinetic energy:

$$hf = W + K.$$



If a high enough stopping voltage is applied on the collecting plate (anode) then even the fastest electrons ejected from the cathode cannot reach it and the photoelectric current drops to zero (see Fig. 2 - http://www.physchem.co.za/OB12-mat/photoelectric.htm):

$$K_{max} = e\,V_s.$$

The above formulas can be combined (the conservation of energy):

$$h\,f = W + e\,V_s, \tag{2}$$

which can be rearranged to give the stopping voltage V_s as a function of the wave number $1/\lambda$

$$V_s = (h/e)\,f - W/e = (hc/e)\ 1/\lambda - W/e. \tag{3}$$

Equipment

- Photoelectric device
- Monochromatic light emission diodes (LEDs)
- Digital voltmeter
- Power supply.

Experimental procedure and calibrations

1. The photoelectric apparatus should only be left on when measurements are being taken. Connect the digital voltmeter set on DC (minimum 2V scale) on the red/black jacks of the photoelectric device.
2. The photoelectric apparatus has two knobs labeled "zero" and "voltage." With the apparatus turned on but the entrance completely blocked, adjust the **zero knob** until the current reading on the apparatus is zero. The voltage reading should also be zero. Once the "zero" knob has been set, the current reading on the apparatus will be adjusted using the "voltage" knob on the apparatus. **After the initial calibration, never during the experiment touch again this "zero" knob.**
3. Insert one LED in the hole of the photoelectric apparatus and secure it. Turn on its voltage (never go over 5 V) and there will be a current shown on the ammeter of the apparatus.

4. To determine the stopping voltage V_s, adjust **the voltage knob** on the apparatus until the current shown by the ammeter of the apparatus is zero. At that moment, write down the voltage measured by the externally attached voltmeter, *i.e.*, the stopping voltage.
5. Repeat steps 3 and 4 for all LEDs (Table 1). When finished turn off the apparatus.

Experimental Data

Table 1. Stopping voltage V_s for different wavelengths.

LED		λ (nm)	$1/\lambda$ (nm^{-1})	V_s (V)
SSL-LX100133SIC	Red	636		
SSL-LX100133SOC	Orange	610		
SSL-LX100133SYC	Yellow	590		
SSL-LX100133SUGC	Green	574		
SSL-LX100133USBC	Blue	470		

Results

1. Plot the stopping voltage $y = V_s$ (in volts) versus the inverse of the wavelength $x = 1/\lambda$ (in nm^{-1}) and attach it to this report. Show the equation for a linear fit and R^2 on the attached plot. Do not connect the points!
2. Compare the experimental slope of $y = V_s$ versus $x = 1/\lambda$ against the known theoretical value of $slope_{theory} = hc/e = 1239.842$ V nm.
   a. Write down the experiment $slope_{exp}$ = _____________________
   b. Compute the percent error of the slope (show all your calculations):

$$Err_{slope} = \frac{|slope_{\exp} - slope_{th}|}{slope_{th}} 100\% =$$

3. According to (3), the intercept of $y = V_s$ versus $x = 1/\lambda$ plot is W/e, which is the work function in eV (electron-Volt).
   a) Write down the work function W = _______________ eV.
   b) Convert W from eV to Joule (show all your calculations):

4. Using the theoretical values of $h_{th} = 6.626068\ 10^{-34}\ m^2\ kg/s$, $c = 299\ 792\ 458$ m/s, and experimental W above (in Joule) to determine the cutoff wavelength:
   $\lambda_0 = hc/W =$

5. Based on the experimental $slope_{exp}$, the theoretical values $e = 1.60217646\ 10^{-19}$ C and $c = 299\ 792\ 458$ m/s, find the experimental value of Planck's constant:
   $h_{exp} = slope_{exp}\ e/c =$

6. Compute the percent error of h_{exp} against $h_{th} = 6.626068\ 10^{-34}\ m^2\ kg/s$:
   $Err_h =$